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Sulfuric sugars and their derivatives. XII. Xanthogenic glucose and its cleavage into glucothiose (1-thio-glucose).

by W. Schneider, A. Gille and K. Eisfeld.

Berichte d. Deutschen Chem. Ges. 61, 1244-1259 (1928). Only designated portions have been translated.

Since we were vitally interested in glucothiose and the glucothiosides derived therefrom in view of the goal we had set ourselves long ago, of synthesizing natural mustard oil glycoside, we again attacked the investigation of these compounds in the present laboratory. The impetus therefor was given by an observation imparted to us some time ago by M. Bergman, to the effect that aceto-bromoglucose can be transformed smoothly to aceto-xanthogenic glucose with potassium-ethyl xanthogenate, a compound which apparently yields glucothiose upon saponification. it was felt that ~~We considered~~ ethyl-xanthogenic glucose (hereafter called xanthogenic glucose) is indeed a favorable starting material for the convenient production of 1-thioglucose on one hand, and suited for the collection of experience in preliminary work aimed at the synthesis of mustard oil glycosides, on the other. We therefore subjected aceto-xanthogenic glucose to closer scrutiny, with the concurrence of Mr. Bergman.

~~We obtained~~ the compound was obtained in two different dimorphous modifications, of which the one with the higher melting point was found to be stable at room temperature. Upon saponification with alkaline agents, especially with methyl alcoholic ammonia, free xanthogenic glucose in fact cannot be isolated, but glucothiose is obtained directly instead. It is noteworthy that we succeeded in splitting off the acetyl groups with acids, without changing the xanthogenate residue on the sugar in the process(1). It is best to accomplish saponification of the acetyl groups with methyl alcoholic hydrogen chloride, but sulfuric acid in methyl alcohol, even aqueous hydrochloric acid will also work under certain conditions.

Xanthogenic glucose,

$$\underbrace{CH_2(OH).CH.CH(OH).CH(OH).CH(OH).CH}_{O}.S\,CS.OC_2H_5$$

crystallizes from concentrated aqueous solution, or better, from water-saturated ether, with 2 moles crystal water. It cannot be obtained in a completely pure form anhydrously. It is conspicuously stable even in aqueous solution and decomposes slowly upon boiling with diluted sulfuric acid in the presence of copper sulfate, with separation of copper(I)-xanthogenate.

I-thio-glucose, forming upon ammoniacal saponification of tetraacetate, has the properties described in preceding papers. Despite a very large number of tests with multifarious changes in the conditions of saponification and isolation (2) the obtained preparations of sulfuric sugar never showed such a high content of sulfur (approaching the theoretical 16%) as found by Wrede;

it amounted to a maximum of 15%, therefore agreed with previous findings (3). Correspondingly exaggerated values were obtained for carbon and hydrogen; thus the presence of 1 mole of water assumed earlier is negated. The acetylation of isolated samples of glucothiose as well as of the syrupy saponificational residue yielded only amorphous products from which pentaacetyl-glucothiose could not be obtained in crystalline form, suggesting that mixtures of various acetyl compounds were present. In fact, we succeeded occasionally in isolating the acetate of diglucosyl disulfide from one such mixture. The disulfide seems to be admixed to the glucothiose in fluctuating but considerable amounts upon ammoniacal saponification without occlusion of air, even during rapid execution. This assumption is supported by the strongly deviating, more or less strongly negative values of the optical rotatory power of variously produced preparations. Strict exclusion of aerial oxygen during the production of glucothiose by ammoniacal saponification of aceto-xanthogenic glucose remarkably enough yielded preparations with an even lower sulfur content, only about 13-14%.

Optical observation of the progress of saponification by methyl alcoholic ammonia revealed that the xanthogenate residue is degraded thereby with considerably higher speed than that required by the cleavage of the acetyl groups. Therefore tetraacetyl-glucothiose must from in the first phase of saponification. This again could not be isolated as such, but we succeeded in obtaining crystallized pentaacetyl-glucothiose, with properties reported by Wrede, in almost quantitative a yield by the interruption of saponification (started at 0°C) after 1 hour, evaporation in vacuo and reacetylation of the syrupy residue.

Attempts to prepare glucothiose from this pure pentaacetate precisely according to Wrede's instructions with methyl alcoholic ammonia did not lead to better preparations than those obtained from the acetate of xanthogenic glucose. Invariably the sulfur content was unsatisfactory. An important step forward in the characterization of glucothiose was achieved, however, when Zemplen's method was used in the saponification of aceto-xanthogenic glucose. This method makes it easy to produce crystalline alkali salts of glucothiose in good yield.

In the following, sodium-glucothiosate, $C_6H_{11}O_5.SNa + 2H_2O$, and the testing of the properties of glucothiose accomplished with it, shall be described in detail (4). The salt can be obtained easily in pure form, it is quite durable when dried in the air and shows surprising stability, even in heat, in aqueous solution under exclusion of aerial oxygen. Its metallic content can be determined acidimetrically in agreement with gravimetric analysis when methyl orange is used as indicator, not so with phenol-phthalein, since glucothiose is a frank, if weak, acid. In the air, in aqueous solution, it oxydizes to diglucosyl disulfide within a few days. Momentary oxydation is achieved by means of hydrogen peroxide. When the destructive effect of surplus peroxide on the formed disulfide is inhibited by weak acidification, a solution is obtained the maximal negative rotatory power of which approaches within a few % the value determined for amorphous disulfide by Wrede.

The silver compound of glucothiose, gained from sodium salt in aqueous-alcoholic solution (it was produced with ammoniacal silver acetate solution in order to retain the sodium as acetate in solution) is identical externally and in constitution with amorphous preparations previously precipitated from

free sulfuric sugar, but differs from those by the complete loss of its water-solubility after isolation and desiccation. The cause of this surprising fact shall be discussed later.

The freshly prepared aqueous solution of the sodium compound is dextro-rotatory (see below) and retains this rotatory power permanently under occlusion of aerial oxygen. It does not show a pronounced mutarotation; insignificant fluctuations in numerical value noted during 10 days of observation in the closed tube may be ascribed to trivial decomposition. Upon acetylation with acetic anhydride in pyridine, the sodium salt yields a single product, beta-pentaacetyl-glucothiose, by reaction with ethyl iodide, beta-ethyl-glucothioside. The formation of the latter was determined by optical observation of the reaction and also by preparative isolation of its tetraacetate. Thus the tested sodium-glucothiosate is unquestionably characterized as the sodium compound of beta-glucothiose.

The true specific rotatory power of pure beta-glucothiose can now be determined easily by adding an equivalent amount of a mineral acid to the newly prepared solution of the sodium salt in water. The test led to the interesting result that beta-glucothiose is also dextro-rotatory, and that the numerical value of the rotation closely approaches the $+20^\circ$ (5) listed in the literature for beta-glucose (see below). It was also important to note that the solution of free sulfuric sugar shows mutarotation. The rotatory value rose, even if slowly, and achieved a maximal final figure after about 10 days. However, during this long period of time a decomposition of thioglucose was notable despite exclusion of aerial oxygen, and this obviously influenced the final rotatory value. The progress of mutarotation is speeded up considerably by the presence of a certain amount of hydrogen ions. When the solution of free glucothiose is given a low excess of free mineral acid (it suffices if the solution-acid ratio is about 1/500-n), a constant maximal final rotation is achieved in about 3 days. In this case it has a higher numerical value, which is not inconsequential (see below) and again is not too far removed from the constant terminal rotation of d-glucose ($+52.3^\circ$). Since no important decomposition of glucothiose was noted under these circumstances — qualitatively, only a minimal separation of hydrogen sulfide was demonstrated — the constant specific final rotatory power of glucothiose determined under these circumstances should largely correspond to the mutarotatory equilibrium of its alpha and beta form.

The discussed specific rotations $[\alpha]_D^{20}$ in water were for:

beta-glucothiose-sodium $+ 2H_2O$ ---- $+15.5^\circ$
beta-glucothiose (initial rotation --- $+16.5^\circ$
glucothiose in mutarotational equilibrium --- $+58.4^\circ$

When the rotation of sodium salt is converted from $+15.5^\circ$ to the basic quantity of sulfuric sugar, a specific rotation of $+20.1^\circ$ is obtained. This value, however, corresponds to the ion of glucothiose, while the value of $+16.5^\circ$ is valid for the compound which is present in a free state in solution, primarily as undissoviated beta-glucothiose. It is noteworthy that a higher concentration of free acid does not influence the speed or the final value of

mutarotation. Since the utilized small excess of acid should be sufficient to almost totally restrain the weak dissociation of free glucothiose, and further, since the sodium salt does not show mutarotation, the conclusion seems justified that only undissociated sulfuric sugar is capable of rearrangement, but not so its ion. The stimulating influence of small quantities of hydrogen ions could then be explained by its effect of neutralizing the dissociation of glucothiose.

The fact of mutarotation of glucothiose gleaned from the optical behavior of acidified sodium glucothiosate solution can also be supported further by preparative methods: When a glucothiose solution was evaporated after adjustment of the mutarotatory equilibrium and the residue subjected to acetylation in pyridine, the resultant acetyl product, which according to its sulfur content had the composition of a glucothiose-pentaacetate, could be split into two different fractions by crystallization, of which the first was identified as the well-known beta-pentaacetate by its low positive rotatory power of about $+ 10^{\circ}$ (in acetylene tetrachloride) and its melting point. The second crystalline fraction subsequently separating from the mother liquor was identified as a new compound by the crystal habit, a melting point higher by several degrees, and mainly by its high rotatory power of about $+ 120^{\circ}$, quite probably containing alpha-pentaacetyl-glucothiose. The possibility is given herewith to investigate the alpha form of glucothiose.

The present examinations already permit the certain conclusion that alpha-glucothiose, similarly to the alpha form of d-glucose, will show a high dextro-oriented optical rotatory power, probably in excess of 100°. Hereby Wrede's (7) assumption, deduced from an initial negative rotatory value of thioglucose from sinigrin observed by him, to the effect that this sulfuric sugar is the alpha form of synthetic thioglucose (dextro-rotatory to start with), becomes untenable. For the time being the nature of glucothiose from sinigrin is still totally unexplained. If it should reveal a negative rotatory power after all — and we hope to clarify this point by production and examination of a crystallizable sodium-glucothiosate from mustard oil glycoside started in this laboratory —, then only a glucothiose with an unnormal lactol ring could be involved. Investigation continues in several directions.

Description of the tests.

I. Xanthogenic glucose and its ammoniacal cleavage (ed. by Rudolf Gille).

Tetraacetyl-d-glucose-ethyl xanthogenate,

$$(CH_3 . CO)_4\ C_6H_7O_5 . S . CS . OC_2H_5 .$$

A hot concentrated solution of 9 g potassium-ethyl xanthogenate in absolute alcohol is poured onto 23 g aceto-bromoglucose. The mixture is brought to the boiling point on the water bath for 5 minutes. Almost instantly copious quantities of potassium bromide settle out. Now water at room temperature is carefully added to the hot reaction mixture in such amounts that turbidity is just visible, and after inoculation with crystals obtained in a preliminary test and sustained

stirring of the initially forming oily emulsion it is allowed to cool spontaneously. The precipitate slowly turns into crystals and the action may be completed by further addition of water. The tolerably pure crude product melts at 87-89°C and is obtained in a yield of almost 90% of the theory. For the purpose of total purification the compound is first recrystallized once from petroleum ether, then again from alcohol. The compound forms colorless, rough prisms with a melting point of 88-89°C, is easily soluble in ether, methyl and ethyl alcohol, acetone, acetic ester and glacial acetic acid, slightly soluble in cold benzene, very poorly soluble in cold petroleum ether.

0.1790 g substance: 0.2945 g CO_2, 0.0871 g H_2O.
0.1563 g substance: 0.2579 g CO_2, 0.0783 g H_2O.
0.1530 g substance: 0.1590 g $BaSO_4$.
0.3002 g substance: 0.3098 g $BaSO_4$.

$C_{17}H_{24}O_{10}S_2$	Calculated:	C 45.09	H 5.35	S 14.17
	Found:	C 44.87, 45.00	H 5.45, 5.61	S 14.27, 14.17.

$[\alpha]^{20}_{D}$ in acetylene tetrachloride (c equals 3.197) =

$$+ 1.97° \times 100/2 \times 3.197 = + 30.8°.$$

In the course of numerous productions of the compound, fine needles were frequently obtained in place of rough prisms, with a considerably lower melting point. Now and then it happened that upon recrystallization of the prismatically crystallizing substance the melting point sank by several degrees and small needles settled out. This phenomenon occurred especially often at the start of treatment with aceto-xanthogenic glucose; later it became more and more difficult to obtain crystals with a lower melting point. The lowest observed melting point of the fine needles was about 74-76°C, but all stages between these and 80°C were observed. The two forms did not differ markedly in constitution and properties, other than that the low-melting modification seemed to have a somewhat lower optical rotatory power than that with the higher melting point. We are apparently dealing here with an unstable modification of aceto-glycoside favored by small impurities, since in the presence of its saturated alcoholic solution the low-melting needles are converted to prisms within 1-2 weeks at room temperature, accompanied by a rise in the melting point. The prisms represent the sole stable form, since they remain unchanged under identical conditions. Exact conditions leading to reliable preparation of the low-melting modification have not been discovered as yet.

Preparation with m.p. 78-82°C: 0.2657 g substance: 0.2801 g $BaSO_4$.
Preparation with m.p. 75-77°C: 0.1683 g substance: 0.2804 g CO_2, 0.0818 g H_2O. --- 0.2189 g substance: 0.3644 g CO_2, 0.1077 g H_2O.

$C_{17}H_{24}O_{10}S_2$	Calculated:	C 45.09	H 5.35	S 14.17
	Found:	C 45.44, 45.40	H 5.44, 5.51	S 14.48

Preparation with m.p. 85-86°C (rough prisms):

$[\alpha]^{20}_{D}$ (c= 3.469) = $+ 2.06° \times 100/2 \times 3.469 = + 29.74°$
$[\alpha]^{20}_{D}$ (c= 2.146) = $+ 1.27° \times 100/2 \times 2.146 = + 29.64°$

Preparation with m.p. 77-81°C (fine needles):

$$[\alpha]^{20}_{D}(c= 1.668) = + 0.96^{\circ} \times 100/2 \times 1.668 = + 29.0^{\circ}$$

Preparation with m.p. 74-77°C (fine needles):

$$[\alpha]^{20}_{D}(c= 1.346) = + 0.73^{\circ} \times 100/2 \times 1.346 = + 27.12^{\circ}.$$

II. Rotation and mutarotation of beta-glucothiose (ed. by Kurt Eisfeld).

Sodium-beta-glucothiosate (beta-glucothiose-sodium),

$C_6H_{11}O_5SNa + 2\ H_2O.$

10 g aceto-xanthogenic glucose is dissolved in 20 ccm chloroform, cooled to -20°C and mixed under continued cooling with 30 ccm of an equally cold sodium methylate solution of 3 g Na: 100. In order to start the reaction, the flask is briefly removed from the cooling mixture, causing the temperature of the contents to rise somewhat, until the separation of the deposited compound takes place in form of a gel. Now the flask is reintroduced into the cooling mixture for 5-8 minutes and the product is decomposed by the addition of about 50 ccm ice water, containing acetic acid, until phenol-phthalein indicates a neutral reaction. Now the aqueous solution is lifted from the chloroform, filtered and compressed in vacuo at 35-40°C, until crystallization sets in. Then a 2-3-fold volume of methyl alcohol is added and crystallization is promoted by the trituration of already formed crusts in the liquid. After 1 hour the product is removed by suction, thoroughly washed with methanol and dried at room temperature and humidity. The yield of salt amounts to 4.8 g, i.e. more than 85% of the theory. The crystals represent compact, rather uniform tetrahedrons which frequently occur in the form of stellar adhesions; they are double-refractory with linear disappearance in one direction. The compound is obtained directly in analytically pure form in this process (preparation I) and melts in the capillary tube upon rapid heating (about 1°C elevation every 3 seconds) after turning brown, at 173-174°C, accompanied by decomposition. Upon slower heating, considerably lower melting points were observed.

If more starting material is used in the production, e.g. 20 g aceto-glycoside all at once, the preparation is not quite as pure, notwithstanding identical analytical results (as shown by a slightly lower dextro-rotation), but may be induced to show the same maximal rotatory value ($[\alpha]^{20}_{D}$ = about +15.5°) by solution in water and crystallization by means of methanol (preparation II). The salt is easily soluble in water, almost insoluble in methyl and ethyl alcohol. It is completely durable in air and does not effloresce noticeably. The crystal water is bound quite strongly and cannot be removed below 80°C even in vacuo, but only by heating at steam temperature for several hours. The browned compound dehydrated in this manner reabsorbs the entire original quantity of water after a few days at room humidity and may be transformed back into the colorless crystals by recrystallization. The sodium content can be determined precisely by titrimetric means in the presence of methyl orange. In tests with phenol-phthalein, the glucothiose isolated from the salt proved to be a distinct acid.

3.423 mg substance: 5.532 mg CO_2, 1.858 mg H_2O.
0.1779 g substance: 0.1636 g $BaSO_4$
0.1958 g substance: 0.0548 g Na_2SO_4
0.1819 g substance: 0.0506 g Na_2SO_4
0.4298 g substance: 16.9 ccm n/10-HCl.
0.1926 g substance: 7.7 ccm n/10-HCl.

0.1607 g substance: loss after 6 hours in vacuo at 98°C 0.0226 g. – after 6 days reabsorbed by the same quantity of substance at room humidity 0.0210 g.

$C_6H_{11}O_5SNa + 2\ H_2O$.

Calculated: C 28.33 H 5.95 S 12.62 Na 9.05 H_2O 14.18
Found: C 28.10 H 6.06 S 12.63 Na * H_2O 14.06 (loss)
13.20 (reabsorption).

* 9.06, 9.01 (gravimetrically)
9.04, 9.19 (titrimetrically)

Preparation I. $[\alpha]_D^{23}$ in water (c= 1.4785) = $+ 0.46° \times 100/2 \times 1.4785$ = $+15.56°$, converted to $C_6H_{11}O_5SNa = + 18.13°$, to $C_6H_{12}O_5S = + 20.16°$.

Preparation II. $[\alpha]_D^{20}$ in water (c= 4.273) = $+ 1.31° \times 100/2 \times 4.273$ = $+ 15.46°$, converted to $C_6H_{11}O_5SNa = + 18.01°$, to $C_6H_{12}O_5S = + 20.03°$.

Glucothiose-sodium is also remarkably stable in pure aqueous solution under exclusion of aerial oxygen; even boiling for several minutes does not cause appreciable separation of sodium sulfide, since the cooled solution shows only a weak yellow color upon addition of alkaline lead solution; only when the compound is reheated in the presence of the reagent, gradual formation of lead sulfide occurs in the proximity of ebullition. The rotatory power also suffers only very gradual and insignificant changes upon storage in the closed polarization tube at room temperature, if boiled water is used as solvent, as has been done in every case. If the solution is allowed to come in contact with air, the rotation soon assumes a negative value, attributed to the formation of disulfide. This does not take place quantitatively, however, and apparently is accompanied by other processes and is partly superimposed, since the substance not only fails to reach the full rotatory power of diglucosyl disulfide ($[\alpha]_D^{18} = -144.4°$) (8), but the observed maximal negative rotatory value suffers a slight decrease after a longer period of time.

Preparation II (see above) in the closed tube stored at about 20°C: alpha after 2 days = $+ 1.21°$, after 5 days = $+ 1.13°$, after 10 days = $+ 1.26°$.

Preparation I (see above) in the half-filled metric flask, daily shaken with air after removal of the stopper and stored at about 20°C: alpha (starting value: see above) after 20 days $-2.15°$ (expected upon quantitative transformation to disulfide: $-3.28°$), after 30 days $-1.91°$.

The formation of disulfide upon exposure to air is revealed also by the reaction of the sodium salt solution to phenol-phthalein. When the fresh solution, reacting in the alkaline area with this indicator, is titrated with n/10 acid, the red indicator hue disappears (very gradually turning pink and pale) already after addition of a quantity equal to the sodium content. If the solution is now exposed to air, it slowly reassumes the red color, apparently because of the formation of the much less acid disulfide. Several days later the same quantity of acid may be added again in order to titrate until colorless. For the titration of the last third of the alkaline metal, methyl orange must be used as indicator, even after the influence of aerial oxygen has ceased.

A rapid and nearly complete transformation into diglucosyl disulfide takes place upon the contact of glucothiose sodium with hydrogen peroxide. However, in alkaline solution an excess of this reagent has a rapid deteriorating effect on the formed disulfide. To prevent this, the solution is either acidified shortly after the addition of peroxide, or the reaction is conducted from the start with a weakly acidified solution. In the latter case oxydation is considerably slower, but a solution is obtained which shows a very slow and slight change in its maximal negative rotatory power.

0.3634 g salt (containing crystal water) dissolved in about 5 ccm water, mixed with 10 ccm 6% H_2O_2 and filled to 25 ccm; immediately observed $\alpha^{18}_D = -2.98^\circ$. ---- 0.4345 g of the same substance, identically dissolved, mixed with 10 ccm 3% H_2O_2 and filled to 25 ccm with water: $\alpha^{18}_D = -3.42^\circ$.

$[\alpha]^{18}_D = -102.5^\circ, -98.4^\circ$, converted to agree with disulfide -133.5°, -128.2°. The rotatory angles diminish rapidly.

0.3131 g of the same substance, dissolved in about 5 ccm water, mixed with 5 ccm 6% H_2O_2, after about 3 minutes admixed with 12.4 ccm n/10-HCl (trace of acid excess!) and filled with water to 25 ccm; immediately observed $\alpha^{18}_D = -2.42^\circ$.

$[\alpha]^{18}_D = -96.6^\circ$, coverted to disulfide -125.8°. The rotatory angle slowly diminishes, after 2 hours $\alpha^{18}_D = -2.12^\circ$.

0.3605 g of the same substance, dissolved in about 5 ccm water, this time first mixed with 15.2 ccm n/10-HCl (= 1 ccm excess), then with 2 ccm 15% H_2O_2 and filled to 25 ccm with water; α^{18}_D after 2 minutes = -0.57°, after 7 min. = -1.72°, after 17 minutes = -2.95°, after 20 minutes = -3.02° (highest numerical value).

$[\alpha]^{18}_D = -104.8^\circ$, converted to disulfide -136.4°.

The rotatory angle only changes very slowly and insignificantly: α^{18}_D after 2 hours = -2.99°, after 4 hours = -2.97°, after 1 day = -2.95°, after 2 days = -2.82°.

Optical properties of beta-glucothiose from sodium glucothiosate.

When aqueous solutions of sodium salt are mixed with a quantity of mineral

acid precisely equivalent to the sodium content, or in slight excess thereof, solutions of free glucothiose are obtained which make the study of the optical behavior of sulfuric sugar possible, since the unimportant quantities of inorganic salt forming thereby should not effect rotation significantly. The following tests show that nearly the same specific rotations are found for glucothiose just isolated from the salt, regardless of whether precisely the equivalent amount of n/10-hydrochloric acid is used or a slight excess (9). In both cases the solutions reveal mutarotation accompanied by an increase in rotatory power. While this occurs very slowly in the absence of free mineral acid, it is speeded up considerably by the presence of acid (the concentration amounted to 1/500 and 1/600 of normality).

Test I: 0.3539 g sodium salt (containing crystal water) ($[\alpha]_D^{20} = +15.46°$), corresponding to 0.2731 g glucothiose, were dissolved with 13.95 ccm n/10-HCl (exactly 1 equivalence, determined by titration against methyl orange) and water to obtain 20 ccm. Immediately observed:

$$[\alpha]_D^{20} \text{ (c= 1.3655 glucothiose)} = +0.45° \times 100/2 \times 1.3655 = +16.48°.$$

Test IIa: 0.3146 g of the same substance, corresponding to 0.2428 g glucothiose, dissolved with 12.9 ccm n/10-HCl (0.5 ccm excess) and water to obtain 25 ccm. Immediately observed:

$$[\alpha]_D^{18} \text{ (c= 0.9712 glucothiose)} = +0.33° \times 100/2 \times 0.9712 = +16.99°.$$

Test IIb: 0.3033 g of the same substance ($[\alpha]_D^{20} = +15.56°$), corresponding to 0.2341 g glucothiose, dissolved with 12.5 ccm n/10-HCl (0.4 ccm excess) and water to obtain 25 ccm. Immediately observed:

$$[\alpha]_D^{23} \text{ (c= 0.9364 glucothiose)} = +0.33° \times 100/2 \times 0.9364 = +17.62°.$$

In all three tests mutarotation was observed in the closed polarization tube, which had been stored at room temperature.

Test I after	α_D^{18}	Test IIa after	α_D^{18}	Test IIb after	α_D^{23}
20 hrs	$+0.74°$	3 hrs	$+0.48°$	15 hrs	$+0.88°$
5 days	$+1.05°$	23 hrs	$+0.92°$	24 hrs	$+0.98°$
7 days	$+1.28°$	40 hrs	$+1.06°$	48 hrs	$+1.07°$
8 days	$+1.32°$	64 hrs	$+1.14°$	64 hrs	$+1.09°$
10 days	$+1.33°$	88 hrs	$+1.14°$	88 hrs	$+1.09°$
$[\alpha]_D^{18} = +48.70°$		$[\alpha]_D^{18} = +58.69°$		$[\alpha]_D^{23} = +58.21°$	

Upon removal of the contents from the tube following test I, a strong odor of hydrogen sulfide was noted. The odor was weak in the other two tests. While the very slowly transpiring mutarotation was accompanied by a considerable decomposition of glucothiose in the first case, and the observed maximal rotation certainly did not correspond to mutarotatory equilibrium, the decomposition of sulfuric sugar in the solutions with an acid excess was so slight that the separated amount of hydrogen sulfide, which doubtless remained

unaltered in solution within the closed polarization tube, upon addition of alkaline lead solution revealed itself only by a very weak yellow color.

The constant final rotatory power of the solutions used in tests IIa and IIb probably correspond very closely to the true mutarotatory equilibrium. It is not changed importantly by the bond between equilibrial glucothiose and alkali:

The tube contents of test IIa were combined with the rest of the solution, which meanwhile had been stored in a closed metric flask; 15 ccm were drawn off with a pipette and filled to 25 ccm with 7.8 ccm n/10-soda lye (calculated at 7.7 ccm) and water.

$[\alpha]_D^{18}$ (c= 0.5827 glucothiose) = $+$ 0.69° X 100/2 X 0.5827 = $+$ 59.21°.

In another test it was demonstrated that a twofold increase in the concentration of free acid (n/250) does not influence either the speed of mutarotation or the value of the constant final rotation to a noticeable degree.

NOTES.

(1) Since glycosidal compounds usually are easily hydrolyzed by acids, this observation may perhaps take on more general significance for the production of free glycosides from their acetates in those cases where, as is the case here, very alkali-sensitive glycosides are involved which, however, are relatively resistant to acids. (2) For detailed data see the dissertation by Rudolf Gille, "On xanthogenic glucose and thioglucose, Jena 1927 (in print). (3) Vol. 47, 1263 (1914). (4) Apparently the potassium salt of glucothiose only crystallizes with 1 mole of water. Since its production with invariably identical optical properties so far has been beset by difficulties, its description shall be dispensed with for the time being. — It should be mentioned that Mr. W. Bielig of this laboratory in the meantime has produced a sodium salt and even a crystallized ammoniacal salt of galactothiose via xanthogenic galactose. (5) Cf. P. Karrer, Lehrbuch d. organ. Chemie, p. 343 (1928). (6) The average value of the individual values of tests IIa and IIb listed in the experimental part. (7) Zeitschrift physiol. Chem. 126, 210 (1923). (8) Cf. F. Wrede, Vol. 52, 1760 (1919). (9) The slightly higher rotations of the solutions with acid excess may be attributed to the mutarotation which occurred between the moment of solution and the reading of the polarimeter.